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The Value of Green Certification on Single-Family Houses in the Chicagoland Area

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Abstract

In the United States, residential buildings alone account for 33% of energy consumption. Rising concerns about environmental impacts due to human consumption, as well as health concerns related to pollution have caused a higher demand for environmentally conscious houses. Homebuilders have responded by providing green certifications for houses, attesting to a building's efficiency in various aspects, such as site design and energy and water consumption. Using Multiple Listing Services real estate data on zero- to five-year-old houses sold between 2010 and 2017 in the Chicagoland area, this study examines whether there is a price premium associated with qualifying for green certification, and whether different types of certification garner different premiums. Based on a hedonic pricing model, ordinary least squares regression suggests that a house in this dataset that qualifies for green certification has a selling price that is 9.49% higher than a comparable house without certification, which translates to a dollar amount of about $45,000.

I. Introduction

Efficiency in the built environment has been a concern since the pollution spikes during the Industrial Revolution, but became a widespread topic of concern after the energy crisis of the 1970s (Stone, 2011). The initial response was higher national standards on energy efficiency in newly constructed buildings, but many felt that these standards did not go far enough. Homebuilders then began to release green certifications for houses that would attest to the house's environmentally conscious aspects that went above and beyond national minimum standards, and branched out into many different areas rather than just energy efficiency. Today, this industry of highly-efficient houses has grown tremendously, as has the amount of different green certifications available, largely due to increasing concerns of human-caused climate change and environmental deterioration. As demand for green-certified housing continues to grow, that should result in higher selling prices for these houses. However, does qualifying for a green certification truly add a price premium to a house, when compared to a similar house that does not qualify for any certification? Moreover, just what is a green certification?

As the topic of green housing has become more prevalent in empirical research and industry publications, terminology has been growing and changing so quickly that it is hard to find a set of words used commonly throughout the industry. High efficiency houses, environmentally friendly houses, sustainable houses, energy efficient houses, zero energy houses; all of these terms refer to a house that is in some way considered "green". But just what is "green", and why does it matter? There are many different types of green certifications, from residential to commercial, regional to international, easily acquirable to rigorously strict. What all certifications have in common, however, is the goal of making a building more environmentally friendly through higher standards. These can include more natural lighting, better building sealing, improved energy efficiency, improved ventilation, or better water management, though there are many other aspects to green houses as well that vary by certification. For the purpose of this research, a green house is one that has the qualifications necessary to receive one of four different certifications; Chicago Green Homes, Leadership in Energy and Environmental Design, ENERGY STAR Homes, or National Association of Home Builders Green. The house does not necessarily have to receive the green certification, but must report qualifying for it. Houses that report qualifying for a green certification, as opposed to having actually obtained the certification, are considered since obtaining the certification can be costly which can deter people from doing so.

These and other green certifications matter for a number of reasons. First and foremost, houses that are built up to the higher standards required by green certifications should be less harmful to the environment. It is beyond question that human development has a direct negative impact on the natural world, but green certifications may help to lessen this impact considerably. Additionally, houses built to green certification standards often use more durable materials. In the long run, this means fewer repairs on buildings, lower maintenance costs, and less likelihood of a building falling into disrepair and detracting from the surrounding community. These houses also have considerably lower utility costs through the higher water and energy efficiency standards required by most green certifications. Not only does this help the environment by reducing consumption, it also helps building owners through lower utility bills.

It is the goal of this paper to investigate if having the qualifications necessary for a green certification significantly adds to the final selling price of a single-family detached house in the Chicagoland area, when compared to a similar house that does not qualify for any green certification. In addition, this paper will attempt to answer whether qualifying for four specific types of green certification affect the final selling price of Chicagoland houses differently. This is done by analyzing a set of 18,325 housing sales that took place between 2010 and 2017 for houses that were between zero and five years old at the time of sale. This dataset is from the Midwest Real Estate Database and was accessed through the Multiple Listing Services website. Ordinary least squares regression is performed on the data using a hedonic pricing model, and it is found that houses that qualify for green certification in this dataset sell for approximately 9.49% more than comparable houses that do not qualify for any green certification, which translates to a dollar value of about $45,000.

The rest of this paper is organized as follows. The Background on Green Certifications section examines the history of green building and compares the four different certifications considered. The Existing Literature section then provides an overview of research that has been done in the past on the topic of green certification in the housing market. The theory of a hedonic pricing model and why it was chosen for this research is then explained in the Theory section. Following this, a Methodology & Data section is included where the empirical model that was derived from the hedonic pricing model and the data are explained. To conclude, the findings are presented in the Results section and their relevant implications are discussed in the Conclusions section.

II. Background on Green Certifications

Today's buildings account for 40% of the world's energy usage, and about 8.8 gigatons of carbon dioxide emissions (USGBC, 2016). In the United States (US), residential buildings alone account for 33% of total energy consumption (Kahn & Kok, 2013). The increasing concern for climate change and environmental damage have spurred a rapid increase in demand for more sustainable options in the residential housing market. This demand was first met in 1990 with the introduction of the Building Research Establishment Environmental Assessment Method, or BREEAM (O'Malley, Piroozfar, Farr, & Gates, 2014). Since then, green building and product labels have increased rapidly to the point where today there are nearly 600 different green product certifications, 100 of which are in use in the US (Vierra, 2016). By building structures that go beyond basic standards, one can significantly reduce the impact of the built world on the natural one. Green structures are found to consume between 15% and 25% less energy than traditional ones, and are often made with materials that have a much smaller environmental impact (Suh, Tomar, Leighton, & Kneifel, 2014).

This study examines the added value of qualifying for green certification on the final selling price of a single-family detached house in the Chicagoland area. Specifically, any house in the dataset that claims to have the qualifications necessary to obtain one of four certifications considered is called “green-certified”, and “green certification” is only used to refer to the following four certifications: Chicago Green Homes (CGH), ENERGY STAR Homes (ESH), Leadership in Energy and Environmental Design (LEED), and the National Association of Home Builders (NAHB) Green. This is because these four green certifications are the only types that the houses in the dataset qualify for. The dataset does contain an “other” category which was not considered due to its ambiguity and high probability of misinformation.

All four green certifications considered are similar in terms of the broad categories of sustainability that are required and what minimum level each house must attain to be considered green-certified. When viewed more closely, however, there is also variation in what each of the certifications entail. CGH was a short-run green certification program started in the late 2000s by the City of Chicago for residents of the city and surrounding suburbs, also defined as the

Greater Chicago Area (Chicago Center for Green Technology, 2009). This program was only for residential buildings, and used a point-based system, with points awarded for different features and aspects of the house that were in some way sustainable. There were seven broad categories on which houses were scored; Sustainable Sites, Energy Efficiency, Materials, Health and Safety, Resource Conservation, Homeowner Education, and Innovation. Each category had a minimum required level, and points were awarded for each additional feature. Based on how many points a building received and what type of building was pursuing certification, it would get either a one-, two-, or three-star rating, with three stars being the highest. This program ended after the new Retrofit Chicago plan was implemented in 2012, which narrowed the focus onto energy efficiency and broadened the scope to include all types of buildings.

ESH is a similar certification program run by the US Environmental Protection Agency with a nationwide user base (ENERGY STAR, 2015). This program is not to be confused with ENERGY STAR appliances. Just because a house uses ENERGY STAR appliances does not mean it has the ESH certification, which is a separate and far more extensive program. ESH uses a checklist rather than different point values to determine the eligibility of a house. Specifically, the program requires that a house has a minimum required fenestration and insulation, heating and cooling efficiency, ventilation, filtration, and water management. This program is based on pass/fail criteria rather than having different levels of certification, and focuses heavily on energy efficiency requirements.

LEED is a program developed by the nonprofit organization United States Green Building Council (USGBC) that is arguably the most widely recognized green certification in the US (USGBC, 2008). This program is quite similar to the CGH program, and actually provided many of the initial categories and checklists that the CGH program ended up using. The LEED green certification system uses points in different categories of sustainability to determine one of four different levels of certification. The categories are Innovation & Design Process, Location and Linkages, Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, and Awareness & Education. There is a necessary minimum requirement in each category, and houses earn additional points for every feature that goes beyond this. These points then determine if the house is rated Certified, Silver, Gold, or Platinum.

NAHB Green, also known as the National Green Building Standard, is a program developed by the National Association of Home Builders to be an industry-standard system for rating houses (NAHB, 2016). This program is quite similar to LEED in that it uses a point-based system across multiple categories to determine what level of certification a house should receive. The categories for this program are Lot Design, Preparation, and Development; Resource Efficiency; Energy Efficiency; Water Efficiency; Indoor Environmental Quality; and Operation, Maintenance, and Building Owner Education. The number of points scored beyond the minimum required lead to a house receiving either Bronze, Silver, Gold, or Emerald certification.

As stated previously, CGH, ESH, LEED, and NAHB are the four green certification programs that are present in the dataset. Each has a minimum requirement for different categories of sustainability that guarantees one program is not too lax in any one area. Common general categories among these four green certifications are energy efficiency, sustainable sites, and water efficiency. Further common categories between CGH, LEED, and NAHB are materials, innovation, and homeowner education. Differences include categories such as atmosphere, linkages, health, and operation. ESH seems to be the most different of the four green certifications with much broader categories and simpler guidelines. While other types of certification certainly exist, these four seem to be the most prevalent in the Chicagoland area. Previous research on the topic of green certifications for residential housing often looks at either some or all of these certifications.

III. Existing Literature

Published works on green topics have been growing tremendously since the first green certification in 1990, and it would seem that the topic is becoming more important, or at least more relevant.[1] The most recent published empirical studies on green-certified housing all seem to ask similar questions. Generally stated, they all ask whether green certification adds to the final selling price of a house. Overwhelmingly, the results suggest that the answer is yes. For the real estate market of California, results from empirical tests on housing data between 2007 and 2012 show a price premium of 2.1%, or about $8,400, also referred to as a green premium (Kahn & Kok, 2013). A similarly-conducted empirical analysis on the Austin-Round Rock real estate market of Texas between 2008 and 2016 found a green premium of 6%, or about $18,420, for all green-certified houses, and an even larger 8%, or $24,560, premium for houses with LEED certification specifically (Hallman, 2017). A green premium is also obtained in a study conducted on the real estate market of Atlanta, Georgia, finding that green-certified houses sold between 2007 and 2010 sell for 11.7%, or $47,000, more than comparable non-green houses (Zhang, Li, Stephenson, & Ashuri, 2017). This study also considered both ESH and a local green certification called EarthCraft separately, and both showed significant price premiums of

[1] In their paper on green building research trends, Darko and Chan (2016) find that between 1990 and 2015 only one of the 61 analyzed papers was published before 2000. Published works then hit a peak of 12 in 2013, with more than a third of published works occurring between 2013 and 2015.

6.7% and 7.1%, respectively. All of these studies use regression analysis that is based on a hedonic pricing model with standard control variables, such as square footage, closeness to amenities, and performance of local schools.

While all of these studies show a green premium in their respective markets, the premiums vary largely. Some of this is due to the specifics of each study's real estate market. Khan and Kok (2013) considered the entire state of California, which is bound to have more low-priced houses than a study like Hallman (2017), where a much smaller metropolitan area is examined. In addition, there are likely to be more houses built with sustainable features in California than in Atlanta or Austin-Round Rock because of the region's larger emphasis on environmental consciousness, which would make green certifications comparatively less valuable in this region.

Another interesting finding from Khan and Kok (2013) was that the green premium of about $8,400 was above the average added input cost of building a house up to green certification standards. The authors concede that the price of certifying a house will vary for each structure, but conclude that the green premium is high enough above most certification costs to be considered a net benefit. This would suggest that pursuing green certification in California is financially beneficial for homebuilders. While the other papers did not focus on this aspect, they found even higher green premiums which could suggest that they too may be above any added input costs.

Previous literature seems to strongly support the hypothesis of a price premium on green-certified houses, and in fact no empirical study seems to have been conducted where a green premium is not found. However, there are different drivers of this seemingly ever-present green premium to consider. The most obvious and most widely studied is the financial benefit of owning a green house. The higher efficiency in green houses leads to lower monthly utility bills that quickly add up to large savings. In addition, green houses are often built with more durable materials, so over the life of the house there will be fewer required repair costs. However, these are not the only benefits to green houses.

Another set of drivers of the green premium are the added health benefits of living in a green house. A Canadian study conducted between 1997 and 1998 on residents of New Brunswick and Nova Scotia found through survey results that the rate of asthma and other air quality related ailments decreased significantly for occupants living in green houses over a one-year period, primarily due to better ventilation (Leech, Raizenne, & Gusdorf, 2004). This study also found that compared to occupants of traditional houses, green house occupants reported less overall irritability, headaches, and difficulty concentrating.

A report by the company E4The Future found similar health benefits. By examining 14 different health impact studies from the U.S. and Canada conducted between 2004 and 2016, this study found that most measured indicators of health showed improvement (E4The Future, 2016). Specifically, in low-income households the rate of asthma fell 12% when the families moved to a green building. Some of this benefit is attributed to the building being newer than the house they moved from, but much of it is still from the better ventilation aspects of green buildings. This reduction in asthma meant that these families had to go to the doctor fewer times, which led to an average annual decline of $400 in Medicaid costs. Beyond just asthma, the total survey sample of families reported 9% fewer persistent colds, a 48% decline in the days during the previous month that residents reported their physical or mental health being “not good”, and 7% fewer headaches, which the researchers attribute to better ventilation, more natural lighting, fewer indoor air pollutants, and other green building aspects.

All of these studies show that there is a green premium and suggest that it is driven by lower utility costs, better health benefits, and a growing concern over environmental impact. Chicagoland is similar to the other tested real estate markets because it is a well-known metropolitan area with a large amount of real estate transaction data and a higher focus on sustainability than many other U.S. cities. Though regression analysis has not been conducted on the Chicagoland housing market, a study by Eco Achievers uses descriptive statistics to investigate the existence of a green premium. This study compared statistics from green and non-green houses such as average sale price, days on the market, and utility costs, among other descriptive statistics, and found that between 2008 and 2016 green houses sold for about 4% more than non-green houses in the Chicagoland real estate market (Eco Achievers, 2017). It is the goal of this paper to expand on Eco Achiever's initial research into the benefits of green-certified houses in Chicagoland by conducting regression analysis on a similar set of data to find if there is a significant green premium when controlling for other determinants of the price of a house.

IV. Theory

Following the existing literature, this research is based on a hedonic pricing model, which states that the price of a good is determined by the characteristics of that good. A more formal definition is given by Black, Hashimzade, and Myles (2009) who write that a hedonic pricing model is "…the method of pricing a good by estimating the value of the individual characteristics that form the good." The origin of this type of valuation method is attributed to Court (1939), where he studied prices with relation to the utility people derive from the goods, which he then theorized would determine the ultimate sale price of the good (Xiao, 2017). Court developed a hedonic price index for automobiles, but his work has led to the use of this model in multiple areas of research, and it has been extensively used to study the housing market.

With relation to housing, the hedonic pricing model allows one to estimate the final selling price of a house by measuring the added value attributed to various characteristics, such as square footage, number of bedrooms, quality of school district, neighborhood crime rate, etc. Each of these characteristics would either add or take away from the value of the house depending on its desirability. Positive aspects, such as air conditioning and a high primary school performance, would raise the value of a house while negative aspects, such as a small square footage and a high crime rate, would lower the value.

It would be erroneous to say that the added value of a feature to a house is solely related to its cost. For example, if a builder decides to add in a fireplace to a house for an extra $1,000, this does not mean the house will then become $1,000 more expensive on the market. This theory thus allows a researcher to estimate the average value added to the buyer of a house from a fireplace far more accurately than just using the price of that feature. It also allows for one to quantify the value of characteristics that do not inherently involve a cost, such as locational and neighborhood characteristics.

There are a large number of possible attributes that could influence the selling price of a house, and the existing literature on the hedonic pricing model for houses tends to group them into four categories; structure, location, neighborhood, and other (Xiao, 2017). Each of these categories has variables that are commonly considered when this model is used for research in the industry. Structure addresses characteristics that are directly related to the construction of the house and includes variables such as lot size, square footage, number of stories, number of rooms, number of bedrooms, number of bathrooms, age of house, structure materials, basement, garage type and number of spaces, swimming pool, fireplace, and air conditioning. Location instead addresses where the house is in relation to important surrounding locales and includes variables such as distance to ocean if near an ocean; view of lakes, rivers, or other natural sites; distance to central business district, employment centers, hospitals, and shopping centers; and accessibility of public transportation. Neighborhood addresses factors of the surrounding community and considers attributes such as crime rate, income of residents, racial composition, and school quality. Some additional variables that have been considered in the other category are distance from landfills, distance to parks, cemetery view, time on the market, and a time trend. Most empirical studies that are based on a hedonic pricing model include a number of housing attributes from each of these four categories depending on what data is available for the region of study. Unfortunately, results are not uniform across studies and vary based on the variables included and model specifications. For the most part, however, results tend to show a positive effect associated with increased lot size, square footage and number of bathrooms, and a negative effect from a greater distance from employment centers, older structures, and low school quality (Sirmans, Macpherson, & Zietz, 2005).

V. Methodology and Data

Following the hedonic pricing model, the empirical framework used in this study is one where the final selling price of a house is a function of its various characteristics. The general form of this estimation is given by:

$$lnSPrice = \beta_0 + \beta_1(Green\ Dummies) + \beta_2(C_2) + \cdots + \beta_n(C_n).$$

In the equation, $lnSPrice$ is the natural log of the selling price of a house adjusted for inflation, β_n is the added value to the house from characteristic C_n, and *Green Dummies* is the set of green certification variables. Inflation adjustment was made by dividing the given selling price of each house by monthly CPI values corresponding to the month and year the house was sold in. Instead of national CPI values, this study uses a specific set of CPI values for shelter in major Midwest cities provided through the Federal Reserve Economic Data website, the "Consumer Price Index for All Urban Consumers: Shelter in Chicago-Gary-Kenosha, IL-IN-WI". This series uses a base year and month of June 2009, which is the bottom of the most recent recession, so all adjusted values are in relation to that time. The semi-log version of this equation is used to account for possible non-linearity, and this functional form is commonly used in empirical research on determinants of housing prices due to the fact that additional features may not be valued at the same dollar value for houses in different price ranges. For example, the added value of an additional bedroom is most likely more for a \$500,000 house than for a \$100,000 house (Sirmans et al., 2005). By using the semi-log model, the value added from each feature can vary proportionally with the size and quality of the house.

Unfortunately, not all the standard housing characteristics were available in the dataset considered for this study, especially those related to location and neighborhood. Many structure characteristics were available, though, and the following structure control variables were included: number of stories, number of bedrooms, number of full bathrooms, number of half bathrooms, square footage, and basement. Basement is a dummy variable, coded as one if the house has a basement and zero if it does not. In addition, dummy variables were included for years and quarters to control for any yearly or seasonal trends. The year dummies should capture the effects of any particularly good or bad selling year not already attributed to the other control variables. The quarter dummies capture the effects associated with the seasonality present in the housing market. It is much easier and more lucrative to sell a house in warmer months, such as June and July, than it is to sell during cold months such as January and February.[2]

To investigate the question of whether green-certified housing in Chicagoland exhibits a green premium, three different sets of green certification dummies are used in this study. The first, called “Green Cert Dummy”, is the simplest and only pertains to the premium of qualifying for green certification. Thus it takes a value of one if the house meets the qualifications for any type of green certification and zero otherwise. The second set of green certification dummies instead addresses whether the green premium is lower for houses that qualify for a single certification than that of those that qualify for more than one, listed as “Single Dummy” and “Multiple Dummy”, respectively. “Single Dummy” is coded as one if the house qualifies for a single green certification, and zero if it qualifies for no certification or more than one certification. “Multiple Dummy” instead is coded as one if the house qualifies for more than one green certification, and zero if it does not qualify for any certification or only a single type of certification. In order to ascertain whether qualifying for different types of green certification yield different premiums, a third set of green certification dummy variables is considered, consisting of “CGH Dummy”, “LEED Dummy”, “ESH Dummy”, and “NAHB Dummy” which stand for each of the four different green certifications present in the dataset. Each variable is coded as one if the house qualifies for that specific green certification, and zero if it qualifies for a different certification or no certification at all. The entries that had multiple listed green certifications were entered into the dummy category that had the lowest count of occurrences.

[2] For this study, quarter one (Q1) includes January, February, and March; quarter two (Q2) includes April, May, and June; quarter three (Q3) includes July, August, and September; and quarter four (Q4) includes October, November, and December.

Also, CGH, LEED, and NAHB each have different sub-levels of certification. However, the number of houses in the dataset that report varying sub-levels of certification is not large enough to make any analysis possible, so when a house lists as qualifying for any sub-level of a specific certification it is placed within its respective category of either CGH, LEED, or NAHB.

These three different sets of green dummy variables are each considered separately in the regression. Thus three different models were considered (A, B, and C), corresponding to the equation using the first, second, or third set of green certification dummy variables, respectively. The full regression equation used is shown below, and a full list describing each of the variables and their expected signs is presented in Table A.1 in the Appendix.

$$
\begin{aligned}
lnSPrice = \ & \beta_0 + \beta_1(Green\ Dummies) + \beta_2(No.of\ Stories) \\
& + \beta_3(No.of\ Bedrooms) + \beta_4(No.of\ Full\ Bathrooms) \\
& + \beta_5(No.of\ Half\ Bathrooms) + \beta_6(Square\ Footage) \\
& + \beta_7(Basement\ Dummy) + \beta_{8-14}(Year\ Dummies) \\
& + \beta_{15-17}(Quarter\ Dummies) + \varepsilon.
\end{aligned}
$$

The dataset used for this research was collected from the Midwest Real Estate Database (MRED) accessed from the Multiple Listing Services (MLS) website. MRED is a collection of real estate data provided by realtors and brokers for the American Midwest, which is defined as northern Illinois, southern Wisconsin and northwest Indiana. The dataset for this study includes all the green single-family detached houses in MRED that were zero to five years old and sold between 2010 and 2017 in the Chicagoland area, which is defined as the City of Chicago and the surrounding suburbs.[3] This entailed 812 houses that qualified for green certification. Typically, a house that qualifies for green certification in the Chicagoland area is a two-story, four-

[3] The database did include 167 green houses that were older than five years, but these entries were omitted due to limitations in the search engine that led to difficulties in determining a comparable set of non-green houses. Given the zero- to five-year age restriction, the sale date of all entries fell between the years 2010 and 2017.

bedroom, 2,600 square foot house with two full bathrooms and one half bathroom, which sells for an average of $390,000.

It is important to note that not all the houses that are considered green in the dataset actually received said certification, nor provide proof of a third-party verification, but all claim to have met the requirements for the certification listed. Many homeowners implement the features necessary for certification without getting a third-party inspection due to the added costs of pursuing verification. Since a house that qualifies for green certification will have the same environmental benefits as a house that pursued third-party verification, both are included in this research.

In order to obtain a comparable set of non-green houses, only zero- to five-year-old houses that sold between 2010 and 2017 with attributes that fell within a similar range for each category of the green houses were considered. This limited the comparable non-green dataset to 17,513 entries, and showed a typical non-green house that is similar in many ways to a typical green house. A typical non-green house is a two-story, four-bedroom, 3,000 square foot house with two to three full bathrooms and one half bathroom, which sells for an average of $475,000. The summary statistics for the data are provided in Table 1.

TABLE 1

Descriptive Statistics for the Chicagoland Housing Dataset

		Inflation-Adjusted Selling Price	No. of Stories	No. of Bedrooms	No. of Full Bathrooms	No. of Half Bathrooms	Square Footage
All Houses (N = 18,325)	Minimum	$85,228.93	1	1	1	0	416
	Maximum	$2,985,961.46	4	7	6	3	10,383
	Mean	$471,123.74	1.90	3.84	2.70	0.83	3,009
	Standard Deviation	$377,028.16	0.46	0.80	0.94	0.48	1,042
	Mode	$191,218.77	2	4	2	1	3,000
Green Houses (N = 812)	Minimum	$86,886.21	1	1	1	0	416
	Maximum	$2,915,354.11	4	7	6	3	10,383
	Mean	$391,622.56	1.87	3.56	2.31	0.79	2,648
	Standard Deviation	$257,435.84	0.52	0.87	0.69	0.45	812
	Mode	$282,287.31	2	4	2	1	2,400
Non-Green Houses (N = 17,513)	Minimum	$85,228.93	1	1	1	0	420
	Maximum	$2,985,961.46	4	7	6	3	10,300
	Mean	$474,809.86	1.91	3.85	2.71	0.84	3,026
	Standard Deviation	$381,268.46	0.46	0.80	0.95	0.48	1,048
	Mode	$191,218.77	2	4	2	1	3,000

By design, the maximum and minimum for each characteristic of green and non-green houses are very similar to each other. It is interesting to note that the mean sold price of non-green houses is greater than the mean sold price for green houses. Houses that qualify for green certification tend to have a host of new features and better technology that should yield a higher selling price, but the other variables not yet controlled for may be driving this difference. Non-green houses have a higher mean value for number of stories, number of half bathrooms, number of full bathrooms, number of bedrooms, and square footage than green houses, which could most likely be causing the higher sale price.

The sales of all houses in the dataset are approximately evenly distributed over the eight years from 2010 to 2017, save for the first year following the bottom of the recession, 2010, which contains very low sales (Table A.2 in the Appendix). The sales data are less evenly distributed over each month (Table A.3 in the Appendix). Housing is a very seasonal market, with late spring and summer months containing more sales than late fall and winter months, though December does have the third-highest number of sales. This is consistent with most other studies on housing market trends.

The distribution of green houses by certification shows whether one type of certification is preferred over another in the Chicagoland area, which is certainly the case. Of the 812 green houses, 765 fall into the ESH category, with the counts for the other three categories only falling between 6 and 21. The prices of these houses also differ greatly. The mean sale price of ESH houses is only $365,000, while the mean sale price for CGH houses is over $1,000,000. LEED and NAHB houses fall closer to the CGH price range with mean prices of about $850,000 and $725,000, respectively. Square footage seems to show the same pattern, with mean square footage values that are lowest for ESH and highest for CGH, with LEED and NAHB falling in between. A similar relationship is also seen in the distribution of houses qualifying for single and multiple green certifications. Multiple certifications have the highest mean sale price and square footage but the lowest count, while single certifications have the lowest mean sale price and square footage but the highest count. The summary statistics for CGH, LEED, ESH, and NAHB data, as well as single and multiple certification data, are provided in Tables A.4 and A.5 in the Appendix.

VI. Results

Ordinary least squares (OLS) regression is used to test the hypothesis that qualifying for a green certification will significantly increase the final selling price of a house. The results of the three models considered are presented in Table 2 on page 20. To address the presence of heteroscedasticity, robust standard errors were obtained for all of the regression results. It is found that qualifying for green certification has a definite and significant positive effect on the final selling price of a house for all three models. Model A shows a coefficient estimate of 0.0907 for the green certification dummy variable. This suggests that having the qualifications necessary to get a green certification on a house raises the final selling price of that house by 9.49%.[4] The mean value of all the houses in this dataset is $471,123.74, so a 9.49% green premium translates to $44,709.64. Model B shows a similar situation. The coefficient estimates for "Single Dummy" and "Multiple Dummy" are 0.0826 and 0.3481, respectively, which translates to an 8.61% and 41.64% green premium. Again, using the mean selling price for all houses in this dataset returns an added price premium of $40,563.75 for qualifying for a single certification and $196,174.93 for qualifying for multiple certifications. A further division of the green certification categories in Model C continues to show the presence of a green premium. The coefficient estimates for the dummy variables associated with CGH, LEED, ESH, and NAHB were 0.3616, 0.3695, 0.0699, and 0.4790, respectively, which correspond to percent changes of 43.56%, 44.70%, 7.24%, and 61.45%. This suggests that qualifying for CGH certification adds $205,221.50 to the selling price, qualifying for LEED certification adds $210,592.31, qualifying for ESH certification adds $34,109.36, while qualifying for NAHB certification adds $289,505.54. The results of Model B and Model C are not good estimates, however, due to the low number of observations for each dummy variable. In Model B, the "Multiple Dummy" only had 24 entries, while "Single Dummy" had 788. In Model C, the "ESH Dummy" had 765 observations while the other three only had 47 split between them. Therefore, conclusions can really only be drawn from the results in Model A.

[4] The transformation to express the regression coefficient as a percentage effect on price is $e^{\beta} - 1$

TABLE 2
Regressions Results of Housing Characteristics on the Natural Log of the Final Selling Price

	Model		
	A	**B**	**C**
Green Cert Dummy	**0.0907*** **	-	-
	(0.0118)		
Single Dummy	-	**0.0826*** **	-
		(0.0118)	
Multiple Dummy	-	**0.3481*** **	-
		(0.0771)	
CGH Dummy	-	-	**0.3616*** **
			(0.1192)
LEED Dummy	-	-	**0.3695*** **
			(0.1364)
ESH Dummy	-	-	**0.0699*** **
			(0.0116)
NAHB Dummy	-	-	**0.4790*** **
			(0.0789)
No. of Stories	**0.0497*** **	**0.0494*** **	**0.0488*** **
	(0.0095)	(0.0096)	(0.0095)
No. of Bedrooms	**-0.0420*** **	**-0.0419*** **	**-0.0421*** **
	(0.0054)	(0.0054)	(0.0054)
No. of Full Bathrooms	**0.2923*** **	**0.2919*** **	**0.2917*** **
	(0.0048)	(0.0048)	(0.0048)
No. of Half Bathrooms	**0.1827*** **	**0.1829*** **	**0.1830*** **
	(0.0082)	(0.0082)	(0.0082)
Square Footage	**0.0003*** **	**0.0003*** **	**0.0003*** **
	(0.0000)	(0.0000)	(0.0000)
Basement Dummy	**0.0405*** **	**0.0402*** **	**0.0402*** **
	(0.0108)	(0.0108)	(0.0108)
2011 Dummy	-0.0130	-0.0128	-0.0125
	(0.0151)	(0.0151)	(0.0151)
2012 Dummy	**0.0429*** **	**0.0431*** **	**0.0431*** **
	(0.0152)	(0.0152)	(0.0152)
2013 Dummy	**0.1497*** **	**0.1503*** **	**0.1507*** **
	(0.0154)	(0.0154)	(0.0154)
2014 Dummy	**0.2429*** **	**0.2440*** **	**0.2450*** **
	(0.0151)	(0.0151)	(0.0151)
2015 Dummy	**0.2586*** **	**0.2595*** **	**0.2601*** **
	(0.0147)	(0.0147)	(0.0147)
2016 Dummy	**0.2469*** **	**0.2475*** **	**0.2475*** **
	(0.0145)	(0.0145)	(0.0145)
2017 Dummy	**0.2449*** **	**0.2455*** **	**0.2454*** **
	(0.0145)	(0.0145)	(0.0145)
Q2 Dummy	**0.0358*** **	**0.0360*** **	**0.0360*** **
	(0.0079)	(0.0079)	(0.0079)
Q3 Dummy	**0.0490*** **	**0.0490*** **	**0.0492*** **
	(0.0078)	(0.0078)	(0.0078)
Q4 Dummy	**0.0340*** **	**0.0340*** **	**0.0341*** **
	(0.0081)	(0.0081)	(0.0081)
Constant	**10.939*** **	**10.940*** **	**10.942*** **
	(0.0212)	(0.0212)	(0.0212)
F-Statistic	**2,579*** **	**2,438*** **	**2,198*** **
Adjusted R-Squared	0.7051	0.7053	0.7057
	N = 18,325	N = 18,325	N = 18,325

Robust standard errors are shown in parentheses underneath the coefficient estimates. Significance at the 0.10, 0.05, and 0.01 levels is indicated by *, **, and ***, respectively.

What this regression analysis shows is that having the attributes necessary to qualify for green certification has a real and significant effect on the final selling price of houses in the Chicagoland area. Moreover, the coefficients for the control variables are all significant and exhibit the expected signs, except for the coefficient for number of bedrooms. This coefficient was negative and significant, which is contrary to what would be expected and what some other housing research shows. While this result is unexpected, it is not completely out of line with the existing literature.[5] A recent study investigating the value of green certification on houses in Austin, Texas also finds a significant and negative coefficient for the number of bedrooms (Shewmake & Viscusi, 2015).

It was found that square footage is highly correlated with the number of bedrooms, which leads to multicollinearity when both variables are included. To determine the robustness of the coefficients, the regression was also run without the number of bedrooms variable and the signs and significance levels of all of the coefficients of the independent variables remained consistent, and their magnitudes varied only marginally. The final reported regressions include both square footage and number of bedrooms because both are standard explanatory variables in the existing literature, and while they are similar in what aspects of the house they capture, they are not complete substitutes.

In addition, the model has a high adjusted R-squared value, suggesting that about 70% of the variation in the final selling price is explained by the independent variables. The independent variables of most interest, the various green dummies, all exhibit positive coefficient estimates

[5] A survey study conducted on 125 empirical research papers, that examine the value of housing based on a hedonic pricing model, found that the number of bedrooms is one of the top 20 characteristics included in these papers. Of the 40 papers which include this variable, 21 show the expected significant and positive coefficient, but 10 show an insignificant coefficient, and 9 show a significant and negative coefficient (Sirmans et al., 2005).

and high levels of significance, which supports the original hypothesis that qualifying for green certification will increase the final selling price of houses in the Chicagoland area.

The results from this study are consistent with previous studies done on different real estate markets. In the areas of California, Austin-Round Rock, and Atlanta significant green premiums are found when compared to similar non-green houses. Moreover, the magnitude of the premiums obtained in this study are in line with those of the existing literature, falling above the lower 2.1% and 6% green premiums of Khan and Kok (2013) and Hallman (2017) respectively, but below the 11.7% green premium found in Zhang et al. (2017). While additional research is needed to make broader claims, it would seem that green premiums persist across multiple different housing markets.

As with any study, this study does have its limitations. The houses in this dataset all claim to qualify for green certification, but some houses actually do not receive the certification while others do. Also, the houses in this dataset seem to be clustered around the high-end of the price range. According to the real estate database Zillow, the average price of a house in the Chicagoland area as of March 2018 was $222,164, which is less than half the average selling price found in this dataset.[6] With the selling price of the houses in this dataset being so much higher than the average value of all houses in the Chicagoland area, there may be self-selection bias because only buyers with high incomes would be able to afford many of the houses in this dataset. Thus this study does find evidence of a green premium in the Chicagoland area, but this premium may primarily apply to houses at the high-end of the price range, and less so for houses at the low-end.

[6] Zillow defines the city of Chicago and the surround suburbs as two separate datasets, so the mean value of $222,164 is an average of the mean selling price of houses in these two areas.

VII. Conclusions

This study examines whether single-family detached houses in the Chicagoland area that qualify for green certification sell for a significant price premium when compared to similar non-green houses. Data for houses aged zero to five years old that were sold between 2010 and 2017, were collected from MRED and accessed through MLS. Using a hedonic pricing model and OLS regression, a statistically significant 9.49% green premium is found, which when applied to the average selling price of all houses in the dataset translates to an added value of $44,709.64. This result is similar to the green premiums found in existing literature.

The reasons for the green premium found in this study are numerous. Houses that qualify for green certification have a direct and meaningful impact on the environment. Better water and energy efficiency significantly reduce the amount of consumption of those utilities; better lot design, building sealing, and insulation reduce the need to heat or cool the house; and better ventilation helps to improve air quality. Such houses also provide benefits to the health of its occupants. Less toxic building materials help to reduce the presence of indoor air pollutants, better ventilation helps to remove any pollutants that remain, and more natural lighting helps to reduce the number and severity of headaches, as well as other ailments. Financial benefits of green-certified houses have also been shown, specifically by Eco Achievers (2017). Many of the features that help with environmental and health benefits also help financially by reducing monthly utility costs, as well as the frequency and severity of repairs.

The environmental, health, and financial benefits all increase the demand for green-certified houses and suggest a significant green premium in the Chicagoland area. Therefore, it can make financial sense for a homebuilder to seriously consider making a number of new single-family houses, especially high-end houses, green-certified. In addition, the presence of a green premium should be of interest to any homeowner considering pursuing green certification, or looking for a way to significantly increase the value of their house.

This study also attempts to examine whether qualifying for a specific type of green certification or for multiple green certifications affects the green premium, but due to a low number of observations in all categories except for single certification and ESH, no conclusions can be drawn. One area of future research could attempt to examine this by using a different set of data. A more extensive dataset, perhaps encompassing a larger geographic area, may solve the problem of a low number of observations and lead to more conclusive results. It could also be beneficial for future studies to consider data from regions that are not primarily metropolitan to examine whether green premiums persist in smaller towns, villages, and even rural communities. The paper by Khan and Kok (2013) considered the state of California, and did include areas that are not metropolitan, but more focused studies are necessary to directly examine the presence of green premiums in smaller communities.

Research on green premiums in the Chicagoland area could also be enriched through the use of quantile regression, as opposed to OLS regression. An issue that can arise when examining the presence of a green premium in housing is that characteristics are often not priced the same over the entire range of housing prices. For example, adding a pool to a lower-priced house might not add as much to the final selling price as it would if it were added to a higher-priced house due to the fact that individuals purchasing a lower-priced house probably care more about the functional aspects of a house rather than luxuries. While OLS regression is not able to account for the possible variation in the value of a housing characteristic that may exist at different segments of the housing price distribution, quantile regression is. Future studies on green premiums, both in the Chicagoland area and in other real estate markets, could thus consider using a quantile regression approach to see if green premiums persist over the entire distribution of housing prices, or are concentrated over a particular price range.

Appendix

TABLE A.1

Variable Names, Descriptions, and Expected Signs

Variable Name	Description	Expected Sign
lnSPrice	Natural logarithm of the final selling price of a house, adjusted for inflation (base period - June 2009)	N/A
Green Cert Dummy	1 = Has the qualifications for green certification 0 = Does not have the qualifications for green certification	+
Single Dummy	1 = Has the qualifications for a single green certification 0 = Has the qualifications for multiple green certifications, or no certifications	+
Multiple Dummy	1 = Has the qualifications for multiple green certifications 0 = Has the qualifications for a single green certification, or no certifications	+
CGH Dummy	1 = Has the qualifications for Chicago Green Homes certification 0 = Does not have the qualifications for Chicago Green Homes certification	+
LEED Dummy	1 = Has the qualifications for Leadership in Energy and Environmental Design certification 0 = Does not have the qualifications for Leadership in Energy and Environmental Design certification	+
ESH Dummy	1 = Has the qualifications for ENERGY STAR Homes certification 0 = Does not have the qualifications for ENERGY STAR Homes certification	+
NAHB Dummy	1 = Has the qualifications for National Association of Home Builders Green certification 0 = Does not have the qualifications for National Association of Home Builders Green certification	+
No. of Stories	The number of stories a house has	+
No. of Bedrooms	The number of bedrooms a house has	+
No. of Full Bathrooms	The number of full bathrooms a house has	+
No. of Half Bathrooms	The number of half bathrooms a house has	+
Square Footage	The square footage of a house	+
Basement Dummy	1 = The house has a basement 0 = The house does not have a basement	+
Year Dummies (2011 – 2017)	1 = The house was sold in that year 0 = The house was not sold in that year Omitted year is 2010	?
Quarter Dummies (Q2 = Apr. – Jun.) (Q3 = Jul. – Sep.) (Q4 = Oct. – Dec.)	1 = The house was sold in that quarter 0 = The house was not sold in that quarter Omitted quarter is Q1 (Jan. – Mar.)	?

TABLE A.2

Distribution of Housing Sales by Year

	2010	2011	2012	2013	2014	2015	2016	2017
All Houses (N = 18,325)	845	2,787	2,623	2,381	2,108	2,384	2,592	2,605
Green Houses (N = 812)	7	64	125	132	181	167	87	49
Non-Green Houses (N = 17,513)	838	2,723	2,498	2,249	1,927	2,217	2,505	2,556

TABLE A.3

Distribution of Housing Sales by Month and Quarter

	Q1			Q2			Q3			Q4		
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
All Houses (N = 18,325)	1,009	998	1,422	1,433	1,646	1,835	1,657	1,817	1,679	1,546	1,576	1,707
Green Houses (N = 812)	36	42	73	98	74	94	74	63	64	65	53	75
Non-Green Houses (N = 17,513)	973	956	1,349	1,335	1,572	1,741	1,583	1,753	1,615	1,481	1,523	1,632

TABLE A.4

Descriptive Statistics for Houses that Qualify for Specific Green Certifications

		Inflation-Adjusted Sold Price	No. of Stories	No. of Bedrooms	No. of Full Bathrooms	No. of Half Bathrooms	Square Footage
CGH (N = 6)	Minimum	$465,732.75	2	4	3	1	2,900
	Maximum	$2,224,052.98	3	6	4	1	6,300
	Mean	$1,053,613.05	2.50	5.00	3.50	1.00	4,300
	Standard Deviation	$661,500.38	0.55	1.10	0.55	0.00	1,193
	Mode	$743,467.06	3	6	4	1	4,000
LEED (N = 20)	Minimum	$194,476.21	1	2	2	0	1,920
	Maximum	$1,444,156.82	3	5	5	3	5,900
	Mean	$856,707.28	2.45	3.75	3.05	1.10	3,485
	Standard Deviation	$392,473.41	0.60	0.97	0.76	0.55	975
	Mode	$1,033,394.89	3	4	3	1	3,800
ESH (N = 765)	Minimum	$86,886.21	1	1	1	0	416
	Maximum	$1,801,435.81	3	7	6	2	10,383
	Mean	$365,085.03	1.84	3.53	2.27	0.78	2,605
	Standard Deviation	$203,290.53	0.50	0.86	0.66	0.45	767
	Mode	$282,287.31	2	4	2	1	2,400
NAHB (N = 21)	Minimum	$354,081.65	1	3	2	0	1,506
	Maximum	$2,915,354.11	4	6	5	1	5,338
	Mean	$726,268.95	2.02	3.81	2.90	0.76	2,947
	Standard Deviation	$600,548.47	0.60	0.68	1.04	0.44	1,166
	Mode	$498,568.09	2	4	2	1	2,769

TABLE A.5

Descriptive Statistics for Houses that Qualify for Single or Multiple Green Certifications

		Inflation-Adjusted Sold Price	No. of Stories	No. of Bedrooms	No. of Full Bathrooms	No. of Half Bathrooms	Square Footage
Single (N = 788)	Minimum	$86,886.21	1	1	1	0	416
	Maximum	$2,915,354.11	4	7	6	3	10,383
	Mean	$380,371.87	1.86	3.54	2.28	0.79	2,625
	Standard Deviation	$239,785.49	0.51	0.87	0.66	0.45	781
	Mode	$282,287.31	2	4	2	1	2400
Multiple (N = 24)	Minimum	$354,081.65	1	3	2	0	1,506
	Maximum	$2,224,052.98	3	6	5	2	6,300
	Mean	$761,020.31	2.17	4	3.29	0.83	3,406
	Standard Deviation	$471,939.46	0.56	0.66	0.95	0.48	1,333
	Mode	$655,558.57	2	4	3	1	1920

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